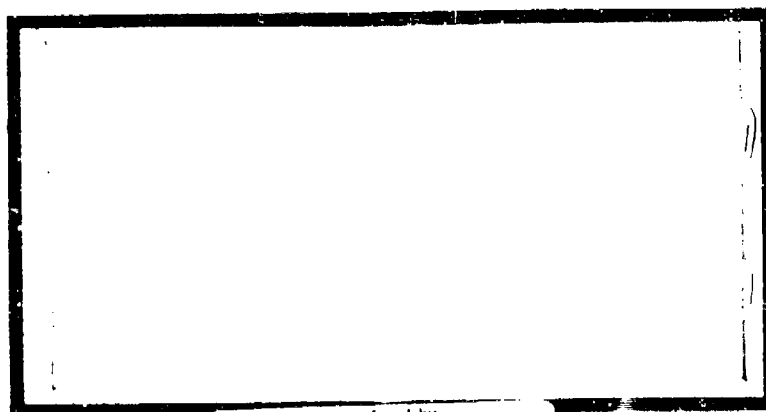


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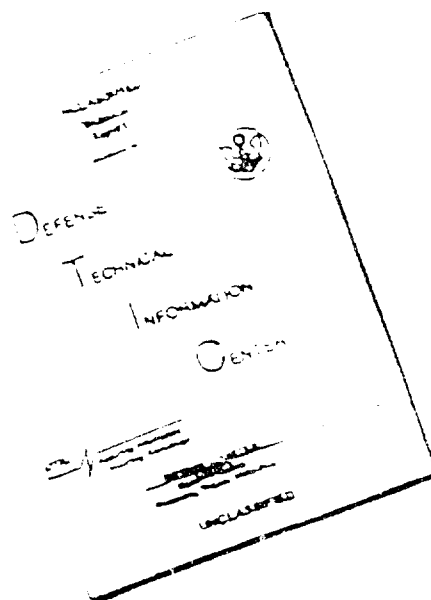


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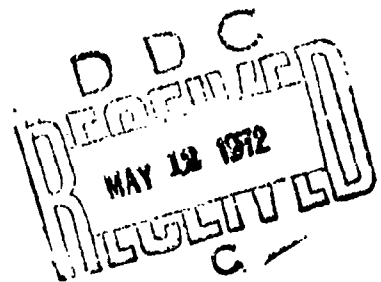
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A CASE STUDY IN SYSTEMS ANALYSIS

THESIS

GSA/SM/72-10

Clifford Miller
Major USAF



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A CASE STUDY IN SYSTEMS ANALYSIS

THESIS

Presented to the School of Engineering
Air Force Institute of Technology
Air University
in Partial Fulfillment of the Requirements
for the Degree of Master of Science

by

Clifford Miller

Major USAF

Graduate Systems Analysis

March 1972

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Preface

This research is the result of a sincere interest in the improvement of the Graduate Systems Analysis program at the Air Force Institute of Technology. It was my aspiration that the product of this research might eventually be combined with other, similar work to enhance the curriculum of this already excellent, rigorous program.

I wish to extend my gratitude to the many people who assisted me throughout this project. Especially, I thank my advisor, Lt. Col. Charles A. Doryland, for leading me to an understanding of what the word "research" implies, and Lt. Col. David L. Belden, who provided the consistent burr under my intellectual saddle. Mr. Richard J. Camp of ACS/ Studies & Analysis and Col. Charles M. Clark, Jr. of the Directorate of Operations, for their invaluable patient assistance in my search for appropriate material at the Headquarters, USAF.

To my wife, for her smooth and efficient management of the family in my "absence", and my children, for tip-toeing past the study door all these months, sincere thanks. You all get A's.

Clifford Miller

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Abstract

This thesis contains a case study in systems analysis, designed specifically for use in the Graduate Systems Analysis program at the Air Force Institute of Technology. The case study was based on an analysis performed in the office of the Air Force Chief of Operations Analysis (since merged with the office of the Air Force Assistant Chief of Staff for Studies and Analysis, under that title).

The case study concerns a coastal radar bomb scoring practice route belonging to Strategic Air Command, which passes close to a commercial nuclear power facility. When a B-52 crashes on the practice route in the proximity of the power plant, interest is suddenly focussed on the possibility of a B-52 crashing into the plant, and the consequences of such a crash. The case study presents the views of several interested parties. An analysis of the problem is then presented, from the viewpoint of an analyst at the level of the headquarters, United States Air Force.

The completely assembled case study, with its accompanying teaching notes, was tested in the classroom through the cooperation of a group of fifteen Graduate Systems Analysis students. The core of the classroom test was a non-parametric statistical analysis to determine if the case study effectively taught a pre-defined tenet of the current doctrine in systems analysis. Several tests performed on the corrected data gave unanimous affirmation that the case study was effective in meeting this specific, carefully defined teaching objective.

A CASE STUDY IN SYSTEMS ANALYSIS

I. IntroductionBackground

Three factors have combined over the last ten years to force upon planners in all the military services, and the Air Force in particular, the realization that the practice of sound systems analytic techniques must be adopted throughout the services. These factors are:

1. The complexity of the diplomatic-political arena in which military decisions are now formulated. Rather than a clearcut set of objectives, the decision maker is often faced with a plethora of competing, and perhaps conflicting, alternatives and contingencies. Even these are in constant flux.

2. The systems employed, the weaponry and supporting networks, have continued to increase steadily in complexity and unit cost.

3. Tightening budgetary restrictions and the employment of systems analysis at the department of defense level to facilitate choices among competing programs, thus forcing the services to "do their homework".

Department of Defense Instruction 7041.3 took official cognizance of this combination of forces in 1969. It spelled out basic philosophy and general applicability of economic

analysis. It made the practice of economic analysis a requirement at all levels where investment proposals are generated. It laid out stringent guidelines for accounting for uncertainty, selecting and applying measures of merit, making comparisons among alternatives, and methods of discounting (Ref 3).

In recognition and anticipation of the growing requirement for professional analysts throughout the Air Force structure, the Graduate Systems Analysis program was established in the Systems Management Department of the Air Force Institute of Technology in 1967.

The student who attends this program is given a broad, well-balanced and logically progressive series of courses which encompass the methodology of systems analysis. He is given courses in finance and economics, since much of systems analysis originated in these fields. These courses enable the student to gain a more sophisticated appreciation of the purpose, or rationale, for employing systems analysis. He is presented a broad and rigorous series of mathematical courses, accenting statistics and operations research. These courses familiarize him with many of the specific tools used in systems analysis. He studies management, examining the history and development of management thought and theory, and comparing the various schools. He is led and encouraged to develop his own framework of management philosophy on the foundation of this knowledge.

The student emerging from this program of study has been offered the knowledge and the opportunity to become a competent technologist. He has some understanding of why, and from where, systems analysis evolved.

The Systems Management faculty has used frequent program reviews and solicited feedback of opinion from graduates, and all users of graduates, to build a 21-month Graduate Systems Analysis curriculum that is strong, current and responsive to the needs of the various users.

The inclusion into the Graduate Systems Analysis curriculum of a set of cases, employing the case study method to illuminate precepts and techniques of systems analysis, with accent on military systems, would enhance the ability of the Systems Management department to achieve its goals in the administration of the Graduate Systems Analysis program. These goals include the production of graduates professionally qualified to serve as systems analysts at any level within the Department of Defense.

Basically, the case study method is one of simulation. Case studies fabricate for the student the environment in which decisions are made in his particular field of study. They enable him to experience typical uncertainties and risks, to practice making decisions in this environment, while he is a student. In several applications, notably the Harvard Business School, the case study method has been found to provide an effective stimulus for the absorption of precepts, the acquisition of skill in techniques, and their application

in concrete situations (Ref 8).

A set of case studies could be effectively employed as adjuncts to the present curriculum. They would also provide another vehicle to incorporate change into the Graduate Systems Analysis program. By simply replacing or revamping case studies as requirements shift for analysts in the field and the technology progresses, the file of cases could be kept always cogent.

At the time the student enters the program, he has probably read the parts of the Air Force Institute of Technology Catalog that pertain to Graduate Systems Analysis. He has most likely read the other prefatory material that came with his notification of acceptance for training. He knows that the Graduate Systems Analysis program is designed to educate selected individuals to function as practicing systems analysts (Ref 1: II-23).

The student is offered specialized knowledge of methods, techniques and tools suited to solving problems of choice under risk and uncertainty. Depending on his academic background and experience, the student could read this statement and say,

"Oh yes, systems analysis is like operations research."

or, "Systems analysis is what industrial engineers do."

or, "Systems analysts are management scientists."

or even, "That sounds like computer systems design."

None of these concepts are wrong; they are all simply incomplete.

One source from which this confusion stems is the indiscriminate use of the title "Systems Analyst" in many sectors of society. In specific applications there is an unspoken prefix such as "Marketing -", or "Computer -", or "Military -", which is understood in the local context of the title. The specific characteristics of the analyses to be performed are likely to be quite different, functions of the nature of the problems to be analyzed. There is, however, a thread of commonality through all the diverse employments of systems analysis (Ref 9:2-5, 418-427). Regardless of the type or scale of the system under scrutiny, the analyst employs a common discipline to identify and bound the problem, quantify factors where appropriate, develop viable courses of action and compare alternatives. E. S. Quade stated it this way:

"Whatever techniques are used, asking the right questions, inventing ingenious alternatives, and skillfully interpreting the results of the computations and relating them to the many nonquantifiable factors are all part of the analytic process" (Ref 9:418).

A set of case studies could be designed to illuminate the common factors, helping the student to achieve a mature image of the profession of systems analysis. The set of case studies could then be expanded to include studies that demonstrate specific techniques, employed in specific situations.

Investigation of the literature and interviews with practicing analysts exposed few current case studies in systems analysis, fewer still in military systems analysis, and none that would be of particular value in the Graduate

Systems Analysis curriculum. Case studies abound in allied or synonymous disciplines; in management, even in military systems management, in finance, operations research and industrial engineering, to name a few. There are many case histories available in military systems analysis, well-documented and ready to be exploited for case studies. Cases could be selected from among these histories to illustrate any precept or technique in current use. The missing link, then, is the selection, construction and evaluation of a set of case studies designed specifically to facilitate the study of military systems analysis.

Problem

There is general agreement among those analysts and educators interviewed that the case study method is a proven teaching technique that would be of significant value in the Graduate Systems Analysis program. It is, in fact, employed in several courses now. The Graduate Systems Analysis program is 21 months long, long for a master's degree program, and the curriculum is a full one. The question of the value to this program of a set of case studies in systems analysis then becomes one of priorities, or comparisons among alternative teaching methods.

In the length of time allotted to thesis preparation, the student researcher can neither assemble a full set of case studies in systems analysis, nor test them against other methods of teaching the same doctrine and techniques.

To make the problem attacked in this thesis tractable, to make possible the selection of a reasonably attainable set of objectives, the first step was to scale down the problem selected for scrutiny.

The specific problem selected for research was that no case study in systems analysis, pertinent to the Graduate Systems Analysis program, was available for evaluation and possible insertion into the curriculum.

Objective

The first requirement for this research project was to develop a case study pertinent to the curriculum of the Graduate Systems Analysis program. This case study should be directed toward exposing some tenet of systems analysis.

The research objective was to verify the case study's effectiveness as a device for accomplishing a specified teaching objective.

A by-product of successful accomplishment of this objective would be a completed case study, suitable for use in the Graduate Systems Analysis curriculum, with teaching notes and the results of a classroom evaluation of its pedagogical effectiveness.

The comparison of this tool with other methods of teaching the same information is beyond the scope of this research effort.

The second chapter of this thesis presents the method-

ology whereby the selected problem was attacked. It outlines the methods used to locate and select the material for a case study. The case study produced through this effort is presented in Appendix 1. The chapter also contains the plan for testing the assembled case study. Some intermediate findings are included, since these modified the final methodology.

The third chapter details the statistical analysis which was applied to the data collected in the classroom, testing the case study. The statistical analysis is necessarily focussed on a specific, narrow learning objective. Results of this analysis say little about the overall value of the case study in the Graduate Systems Analysis curriculum and nothing about its comparative effectiveness vs. other teaching methods.

The fourth chapter contains the conclusions with respect to the research objectives, and some extrapolations based on the research experience. Several suggestions for further research are included in this chapter.

II. Research Methodology

The research and analysis described in this thesis were conducted according to the following outline.

1. Initial Research
 - a. Literature Survey
 - b. Case Histories
2. Case Study Development
3. Case Study Testing and Evaluation
 - a. The Sample Group
 - b. Test Chronology
 - c. Quiz Scoring Method

Initial Research

Literature Survey. A general survey of the literature pertaining to systems analysis proceeded from two starting points; selective use of the bibliographies in some of the test books, reference books and assigned readings encountered in the Graduate Systems Analysis program, and a title search in the library of the Engineering Department of the Air Force Institute of Technology, using the key words "systems" and "analysis". Through the cross indexing system, this title search also encompassed the material in the libraries of the schools of Civil Engineering and Systems and Logistics. The first culling employing these two starting points exposed a rich source of background material pertaining to the evolution

and practice of systems analysis, but no case studies were found.

A bibliographic search of the Defense Documentation Center produced more useful material, much of it focussed directly on the practice of military systems analysis. Included in this material were several detailed case histories suitable for the development of case studies which would be of use in the Graduate Systems Analysis program.

Case Histories. A sample of available case histories in systems analysis was taken at Headquarters, United States Air Force and the Department of Defense. The purpose of this sampling was to test the availability of such historical information, for the development of case studies designed for use in the Graduate Systems Analysis program. A compendium of informed opinion and advice regarding the development of case studies in systems analysis and their significance as teaching tools was a valued by-product of this effort.

A series of interviews was conducted with 19 practicing systems analysts in four organizations; the offices of the Assistant Secretary of Defense (Systems Analysis), the Director of Defense Research and Engineering, the Air Force Assistant Chief of Staff for Studies and Analysis, and the Chief of Operations Analysis, Air Force (These last two have since merged under the Assistant Chief of Staff for Studies and Analysis.) Two of the analysts interviewed were graduates of the Graduate Systems Analysis program at the Air Force Institute of Technology.

In each interview, the researcher was introduced as an Air Force Institute of Technology student, collecting information for the assembly of a case study (or studies) in systems analysis, in fulfillment of the thesis requirement for the Graduate Systems Analysis program. Each respondent was asked to provide examples of the kinds of things he did as a practicing analyst.

All of the 19 analysts interviewed expressed interest in the formulation of case studies in this field. Each presented at least one case history which he felt would be useful in case study preparation. Fifteen of the 19 offered unsolicited opinions that the employment of this teaching method would be of unique value in the formal education of military systems analysts. Several of these suggested that such a set of case studies would constitute an efficient form of introductory material for inexperienced analysts on their arrival in the field. The two alumni of the Graduate Systems Analysis program were among this group. Ten of the 19 offered suggestions pertaining to case selection and case study formulation. These suggestions ranged over such subjects as the kinds of things case studies in systems analysis should be designed to expose, some effective vehicles for case study presentation, and weaknesses observed among neophyte systems analysts. Some specific suggestions were:

1. "Case studies I have seen in this field are not provocative. They should include such factors as policies, politics and personalities."

2. "...we don't get problems pre-defined."
3. "A realistic case study could be programmed for student/computer interaction. Such a program could have built-in dilemmas, irrelevant data, conflicting goals and options for which no feasible solution existed."
4. "Avoid 'school solutions'..."
5. "The analyst should be convinced early that doing a complete analysis is half his job. If he cannot communicate his results to a decision maker, in terms tailored to the decision maker's biases, he has accomplished nothing."
6. "Two problems that I encounter frequently are where to get the data I want in the form I desire, and what terminology encountered in a problem has a specialized meaning within that system."
7. "Analysts should not be surprised when political realities intervene between their completed analysis and its application to help make decisions."
8. "The analyst must remain objective and entirely rational."
9. "Not enough time is spent on carefully defining problems before we start to solve them. As a result, much redefinition is often required."

At first look, suggestions 1 and 5 seem to clash with suggestion 8. Further logical consideration reveals that all three suggestions can be accommodated by the working analyst, and the researcher in his preparation of a case study. He must recognize the politics, personalities and biases for what they are; constraints on the range of viable alternatives, just as real and probably just as rigid as any physical parameter. This kind of abstruse realization could well be brought to systems analysis students through the vehicle of the case study. The case history selected for development in this thesis certainly demonstrates

constraints imposed by politics, personalities and biases.

Case Study Development

Case studies in a set such as the one proposed here would fall into one of two categories; those which were designed to illuminate the tenets of a doctrine of systems analysis, if such a doctrine exists, and those tailored to the exposition of a specific technique. The overlap between these categories is obvious. If a doctrine of systems analysis exists, its tenets must by definition appear within the fabric of the cases. The distinction here is between the explicit teaching of a tenet, the focussing of a case study on it, and the demonstration of a specific technique through which the doctrine would flow in the background.

Does such a doctrine exist? This particular area is rife with possibilities for semantic argument; abstract nouns such as "principle", "doctrine", "precept", "tenet" and "element" mean quite different things to different people. E. S. Quade has listed twelve "precepts" for the systems analyst:

1. Pay major attention to problem formulation.
2. Keep the analysis systems oriented.
3. Never exclude alternatives without analysis.
4. Set forth hypotheses early.
5. Let the question, not the phenomena alone, shape the model.
6. Emphasize the question, not the model.
7. Avoid overemphasizing mathematics and computing.
8. Analyze the enemy's strategies and tactics.
9. Treat the uncertainties explicitly.
10. Postpone detail.
11. Suboptimize with care.
12. Do what you can.

(Ref. 9:419)

Charles Hitch identified four essential "elements" of systems analysis:

1. An objective or objectives which we desire to accomplish. Alternative techniques or instrumentalities (or systems) by which the objective may be accomplished.
2. The "costs" or resources required by each system.
3. A mathematical model or models; i.e., the mathematical or logical framework or set of equations showing the interdependence of the objectives, the techniques and instrumentalities, the environment and the resources.
4. A criterion, relating objectives and costs of resources, for choosing the preferred or optimal alternative. (Ref 6:2,3)

C. T. Whitehead pointed out four particularly important "characteristics" that distinguish systems analysis:

1. Emphasis on understanding the structure behind the decision.
2. Emphasis on explicitness of the analysis.
3. Emphasis on the recognition and treatment of uncertainty.
4. Emphasis on goal directed rather than problem directed action.

For the purposes of this study, the common thread running through all systems analyses is referred to as doctrine. Individual elements, or precepts of this doctrine are called tenets of the doctrine.

The first few case studies presented to Graduate Systems Analysis students should illuminate any tenets which are requisite to the practice of sound systems analysis. Three precepts were encountered with such consistency in analyses and writings in the field that they are listed and

defined here as tenets of a doctrine of systems analysis:

THE PROBLEM: The analyst must identify the specific problem at hand; its components, objectives and constraints.

MEASUREMENT: Selection of a common measure of merit makes possible rational comparisons among alternatives.

SIMPLIFICATION: The analyst reduces problems to workable proportions by identifying variables and parameters to which the system under analysis can be shown to be functionally related, and conversely, eliminating those variables to which the system remains invariate or relatively insensitive. (This tenet is the underlying rationale for the technique of modeling.)

In keeping with the opinion that doctrine should be illustrated by the first case studies offered in the proposed set, and in response to the most repeated suggestion from practicing analysts, the primary teaching objective of the case study developed here was elucidation of the tenet of THE PROBLEM. This objective was subdivided into two parts for clarity and to facilitate measurement of its achievement.

The ultimate teaching objective of the case study was to help the student gain an understanding of the tenet of THE PROBLEM.

The immediate teaching objective was for the student to recognize the importance of this tenet and apply it effectively, in his development of a definition of the problem for analysis.

The case study was designed to expose the importance of rational and objective examination of the total system

involved, its environment and its components, to expose the base problem. It shows a welter of conflicting secondary and parochial problems which obscure the base problem, most of all from the protagonists.

A whole hierarchy of teaching objectives could be formulated for this case study. The tenet of SIMPLIFICATION is amply illustrated in the analysis portion of the study, for example. Only the ultimate and immediate teaching objectives relating to the tenet of THE PROBLEM were set forth here because these furnish the basis for the classroom evaluation of the case study's pedagogical effectiveness. The teaching notes were prepared with a broader viewpoint and list several subsidiary objectives.

The case study presented here (Appendix 1) was written in two parts, or cassettes; a scenario (Casette 1), and an analysis (Casette 2). The scenario contains enough information to allow the student to arrive at a complete, concise definition of the problem for analysis. The analysis develops one such complete and concise definition and proceeds through a plan of analysis and an actual analytic process to a report of the completed analysis. The conclusions reached by appropriate decision-makers are not explicitly presented.

While the TRINON POWER PLANT PROBLEM, the subject of this case study, is disguised as to dates, people and places, it is very similar in content and development to a recent Air Force problem. In the real situation, as in the case study, the various agencies were preoccupied with their

version of the problem to the exclusion of any efficient concerted approach toward a solution. In the real situation, as in the case study, when the total system was viewed objectively, the problem became clear and succumbed to a rather simple Bayesian analysis. The result of this analysis brought agreement from all the protagonists that a serious problem simply did not exist!

To insure that the case study developed here would satisfy the first stated research requirement of pertinence to the Graduate Systems Analysis program, only case histories in military systems analysis were considered. The following criteria were applied to potential case study source material:

1. The case history must pertain to contemporary Air Force problems and their analyses.
2. The case history must demonstrate the use of methods or procedures encountered in the Graduate Systems Analysis curriculum, or otherwise relate directly to the course material.

The case histories considered all originated from organizations whose function was analysis, at Headquarters, United States Air Force and the Department of Defense. They were all suggested by practicing analysts in these organizations in response to a request for examples of the kinds of things they did as analysts. It was therefore considered axiomatic that these case histories satisfied the first criterion. The histories considered for case study formulation were examined and judged individually as

regards their satisfying the second criterion.

The case history from which the case study was abstracted satisfied these criteria.

Case Study Testing and Evaluation

The Sample Group. The completed case study was administered to a group of fifteen students near the end of their first quarter of study in the Graduate Systems Analysis program. Case teaching was conducted employing the teaching notes developed with the case study. The classroom evaluation was conducted in two sessions of 50 minutes each, separated by two days.

The case study testing plan included the establishment of a baseline of knowledge and aptitude concerning the tenet of THE PROBLEM, by the administration of a two-part quiz after the students had read the scenario but before any discussion took place. Anticipated responses to this quiz were precoded to enhance the objectivity of the scoring. The resulting integer scores were considered elements of an ordinal scale.

Similar quizzes were prepared for administration after the students had discussed the scenario but before they had read the analysis, and again at the end of the exercise. Paired responses were to be analyzed using non-parametric statistical techniques.

The final quiz contained a third part designed to elicit general comment and criticism of the case study, and to determine the student's opinion of what he had learned.

The measurement of learning outcomes focussed on the ultimate and immediate teaching objectives of the case study (as defined on page 15). The students were tested and retested to determine their progress in learning and applying the tenet of THE PROBLEM in their analysis of this case study.* Since there was no reason to assume any particular distribution for the students' prior knowledge or aptitude toward this learning outcome, non-parametric statistical techniques were employed. The statistical analysis is explained in detail in the following chapter (pp. 31-40).

The sample group was selected by a less than random procedure; they constituted all the first-year Graduate Systems Analysis students available to the researcher. There is no scientific way to exactly relate the results obtained by administering the case study to this sample group, with expected learning outcomes among the universe of Graduate Systems Analysis students.

The test group was not under the pressure of striving for a grade; another factor which operates against their being a representative sample.

Several facts support the extrapolation of the test results to apply to Graduate Systems Analysis students in general, however.

* THE PROBLEM was defined previously in this thesis. The definition is repeated here for the reader's convenience: "The analyst must identify the specific problem at hand; its components, objectives and constraints."

1. The pressures of competition among the students, once interest was aroused in the developing case study, were intended to serve as an adequate substitute for the missing grade incentive. Evaluation of student participation in the discussions and the results from the quizzes indicated that this substitute incentive did in fact occur. In the first discussion, a lively debate among seven of the fifteen students continued past the end of the class period. In the second session, the discussion ran ten minutes longer than the thirty minutes allotted, and was arbitrarily interrupted by the researcher; administration of the final quiz was a requirement of the testing plan. In both sessions, 40 verbal contributions, from 11 of the 15 students, were recorded.

2. Students for the Graduate Systems Analysis program at the Air Force Institute of Technology are chosen from among Air Force officers and eligible civilian employees of the Air Force, through a screening process that insures some homogeneity of educational experience among the students. Each prospective student must possess a bachelor's degree in engineering, chemistry, physics, mathematics or be a graduate of a service academy. He must have a cumulative grade point average of at least 2.5 on a scale of 0 to 4, or its equivalent. In addition, each prospective student's record is evaluated by a trained counselor in the Air Force Institute of Technology's Admissions Division. This counselor looks for Graduate Record Examination scores well above the norm (The present requirement is for a total score of 1150,

with at least 650 on the quantitative portion. This requirement is flexible). He looks in detail at the prospective student's transcripts, evaluating the student's academic background based on the schools attended, the progression of courses, and grades in certain key courses. He looks particularly for a strong quantitative foundation; mathematics through integral calculus with at least a 2.7 mathematics average. Each prospective Graduate Systems Analysis student's record is then forwarded to the Systems Management department for further evaluation, acceptance or rejection.

3. Acceptance of an assignment as a student to the Air Force Institute of Technology is voluntary, which suggests a common positive disposition toward the program, at least among new arrivals. Such an assignment carries with it an additional active duty service commitment of three times the length of the course, for all officers entering the program. Acceptance of an assignment to the Graduate Systems Analysis program therefore constitutes acceptance of a substantial commitment to the Air Force.

Since the test group should possess these characteristics in common with all Graduate Systems Analysis students, and since the evaluation of the case study produces only a qualitative conclusion as to its effectiveness in teaching the test group, it is probably accurate to extend this conclusion to the case's effectiveness when employed to teach any group of Graduate Systems Analysis students in their first quarter of the program.

The desks in the classroom were numbered before the first testing session, and students were asked to use this number to identify their written responses to the quizzes (and to use the same number for all three quizzes). Numbers were used in lieu of names for three reasons:

1. Grading numbered examinations should assist the researcher to divorce his prior knowledge of some class members from the evaluation, and preserve objectivity.

2. The anonymity implied by numbered responses was expected to encourage the respondents to reply more freely (and critically) to the final question of Quiz 3, which was a general request for comment on any phase of the case study, and opinion as to its teaching effectiveness.

3. The responses, being numbered, were labeled and grouped for handy reference and analysis.

Test Chronology. The first classroom testing session was opened with an introduction, the researcher explaining that the case study was a thesis project; that the group's responses would be used to evaluate the case study. The students were reminded that the case study method of instruction depends upon critical interaction among the group. Cassette 1 was distributed, and the following definition was written on the chalkboard:

"Issues = points of contention to be decided among the parties or their protagonists."

Use of this term in the second part of each quiz required that a common meaning be established early in the exercise.

The students were asked to read Casette 1 and respond to the first quiz (Figure 1, p. 28). This quiz was to establish a baseline for students' knowledge and ability to apply the tenet of THE PROBLEM. After this quiz was collected, discussion was initiated by asking one student to propose his definition of the problem to be analyzed. This discussion continued for 25 minutes, 5 minutes past the end of the period. While the shape of the problem was becoming clear, no real consensus definition emerged from this session. Each student left with cassette 1 and the second quiz (Figure 2, p. 29), for completion before the next session.

The second class session started with collection of Quiz 2 and distribution of Casette 2. After twenty minutes, discussion of the problem as defined in the case study was initiated. The elements of the definition were written on the chalkboard and modified as the discussion dictated. The discussion was arbitrarily cut off after 40 minutes in order that the final quiz (Figure 3, p. 30) could be administered. This requirement of the case testing schedule injected an artificial upper limit on the process of learning through intellectual interaction. It appeared that most members of the test group were involved in the problem, and learning from each other, when discussion was halted. Discussion of the problem definition given in the case study, the group's definition, and the real case from which the study was developed, resumed after the quiz and continued for several minutes after the class period. Discussion ended with speculation

about how the problem would change if the probability of interaction between a B-52 from Oil Burner 28 and the Trinon Power Plant were higher.

The teaching notes for Casette 2 were modified after case testing to accomodate these facts, and to propose ways to better exploit the teaching potential of the case study.

Quiz Scoring Method. The three quizzes each contained two parts intended for use in evaluating the teaching effectiveness of the case study.* The final quiz contained a third part; an open request for comment or criticism on any part of the case study.

The first part of each quiz required a definition of the problem for analysis, from the viewpoint of an analyst at Headquarters, United States Air Force. Responses were awarded integer scores from 0 through 9 based on the following criteria. The definition of the problem as stated by Capt. Masten in Casette 2 (p. 67) was used as an example of one complete, concise definition. It was:

"The possibility of a B-52 crashing into the Trinon Nuclear Power Plant and causing a nuclear accident while engaged in a high-speed, low-level RBS run on Oil Burner 28."

* The quizzes are included here as Figures 1, 2, and 3, pp. 28-30.

Explicit recognition of the element of chance of an interaction between a B-52 on Oil Burner 28 and Trinon Power Plant was awarded two points (double box), and each of the other boxed elements was awarded one point. If any definition contained the six elements (seven points), it would be judged overall for clarity and conciseness and awarded an additional 0, 1 or 2 points. The scale thus established was declared to be ordinal. This declaration of ordinality amounts to assuming that the relative weights, or "values", of the boxed elements is represented by its point count accurately enough that, given n , an integer from 0 through 6, there is no combination of n points which represents a total "value" of the response as high as any combination of $n+1$ points. "Value" relates to adequacy of the response in defining the problem. Since the 8th and 9th points are awarded on a subjective decision, based on the quality of responses which contain the six scored elements, scores of 7, 8, or 9 are defined as ordinally arrayed on the same scale.

The declaration of ordinality is treated as an axiom here. It is certainly not provable within the data. It is, however, a less stringent assumption than that commonly employed in educational measurement and behavioral research, in which responses are assigned exact weights on an interval scale.

The possibility that valid responses entirely different from those expected, and therefore not directly scorable using the pre-coded responses, required consideration.

Since neither time nor students were available for a pre-test evaluation of the questions, it was decided that responses of this type would be evaluated on their own merit and awarded a "comparable" 0-9 score. This requirement did not emerge in the course of case testing.

The second part of each quiz simply asked for a list of the relevant issues. The scoring plan involved awarding one point for each relevant issue listed, no points for issues listed but not relevant, and minus one point for items listed which were not issues. A combination of factors rendered this part useless for objective scoring and for testing the desired learning outcome. There appeared to be considerable confusion as to what comprised an issue, even given the specific definition of "issue". Data, points for research and facts drawn from the data were all included in lists of issues. The relevant issues could be grouped and divided in many different ways. This tended to invalidate any inference drawn from the counting of issues identified. As the analysis progressed, the list of relevant issues changed. If, for example, the probability of a B-52 from Oil Burner 28 striking the Trinon Power Plant is shown to be negligible to the satisfaction of all parties, then no issues remain.

Even though the second part of each quiz was discarded in evaluating the teaching effectiveness of the case study, it served a purpose in the quizzes by helping the students organize their conception of the problem.

The third part of the final quiz, eliciting criticism on any part of the case study and its teaching value, read:

"Comment on anything about the case study; the content, the method, the format. What did you learn?"

This attempt to garner constructive criticism gathered only bouquets. Nevertheless, the comments are listed in Appendix 3 and discussed in the next chapter (p. 38).

Quiz 1

QUESTIONS TO BE ANSWERED AFTER READING CASSETTE 1

The space after each question should be sufficient for your response. If more space is needed, number and continue your responses on the back of this sheet.

1. You are an analyst at Headquarters USAF. Define the problem, from that viewpoint.

2. What are the relevant issues?

Figure 1

Quiz 2

QUESTIONS TO BE ANSWERED AFTER READING CASSETTE 2.

The space after each question should be sufficient for your response. If more space is needed, number and continue your responses on the back of this sheet.

1. Now that you have read the complete analysis accomplished by Capt. Masten, restate your definition of the problem.

2. What are the relevant issues?

III. Analysis of Case Testing Results

Statistical Tests

Scores from the first part of each quiz are compiled in Table 1, page 33. Differences in individuals' scores between quizzes 1 and 2, and 1 and 3, are also included in this table. These differences furnish the data for the statistical tests employed.

The objective of the statistical testing was to determine if employing "The Trinon Power Plant Problem" case study in the manner described was effective in teaching the tenet of THE PROBLEM. The students' understanding and application of this tenet in their analysis of the case study were measured. The null hypothesis was:

H₀: Among the sample group of Graduate Systems Analysis students, the average understanding of, and ability to apply, the tenet of THE PROBLEM after studying the case by the case study method does not exceed the average of this knowledge and ability before studying the case.

As stated, this hypothesis implies a one-tailed test; the students learned significantly or they did not. The event of a negative average learning outcome was rejected by assumption. This entering assumption was verified by the test results. The term "average" is used here in the most general statistical sense, meaning that value which is typical or representative of the underlying distribution. The best estimator of this parameter may be the mode, the median,

the arithmetic mean or some other parameter of the sample population, depending on the nature of the underlying distribution. Since no knowledge of the nature of this underlying distribution is assumed or obtained from the analysis, the "average" is never explicitly estimated. The arithmetic mean, mode and median of the samples are all calculated and given in Table 1, page 33. All of these parameters are estimators of central tendency for many distributions, and therefore, estimators of the "average" for these distributions. It could be stated at this point in the analysis that if the mean or the median is an appropriate measure of the average of the distribution of the knowledge and aptitude being measured, then the average increased from the first quiz to the second, and from the first quiz to the third.

A requirement of this analysis was to test the null hypothesis without attempting to identify the underlying distribution. A level of significance, α , was chosen to be .05. This is equivalent to requiring that repeated testing will erroneously reject the null hypothesis (reject it when it is true) no more than 5% of the time. Rejection of the null hypothesis implies acceptance of the alternative hypothesis, which is:

H_1 : The average understanding of, and ability to apply, the tenet of THE PROBLEM was increased by studying the case.

The first non-parametric statistical test employed was the Sign Test of Paired Observations (Ref 12:16-5.1). From the differences in the scores between quizzes 1 and 2

Table 1
SCORES FROM CASE TESTING QUIZZES

Respondent Number	Quizzes			Differences	
	1	2	3	1 to 2	1 to 3
7	9	6	9	-3	0
8	4	6	4	+2	0
9	4	3	3	-1	-1
11	5	7	7	+2	+2
12	0	4	4	+4	+4
13	1	1	2	0	+1
14	3	6	5	+3	+2
15	4	8	5	+4	+1
16	6	6	6	0	0
17	0	2	3	+2	+3
18	4	7	7	+3	+3
19	7	9	9	+2	+2
20	4	0	4	-4	0
21	1	2	2	+1	+1
22	6	6	6	0	0

ARITHMETIC MEAN	3.80	4.866	5.066
MEDIAN	4	6	5
MODE	4	6	4

(discussion of the scenario presented in Casette 1 intervened between these data points), the following results were achieved:

$$n = 12$$

$$r = 3$$

$$r_{(.05,12)} = 2$$

Where: n = number of paired responses exhibiting a difference.

r = number of occurrences of a negative difference.

$r_{(\alpha,n)}$ = the tabulated critical value of r for the specific values of α and n .

By the decision rule of this test, H_0 is rejected if r is less than or equal to $r_{(\alpha,n)}$. Therefore, in this case, the test fails to reject the null hypothesis at this significance level. From the differences in the scores between Quizzes 1 and 3 (discussion of the scenario, individual study and discussion of the whole case intervened between these data points), the test was similarly applied and the following results were achieved.

$$n = 10$$

$$r = 1$$

$$r_{(.05,10)} = 1$$

By the decision rule, H_0 was rejected for this set of paired observations.

The only assumptions required for this test to apply are that extraneous variables are constant between observations and that the underlying distribution is continuous over the range of the data.

The test focuses on the frequency of occurrence of the negative learning outcome. The same data and the same testing rationale can be used with a different type of tables to obtain the critical probability under H_0 directly (Ref 11:68-70, 250). This employment of the statistics developed in the last tests yields:

$$(\alpha = .05)$$

Quiz 1 to 2

$$n = 12$$

$$r = 3$$

$$p = .073$$

Quiz 1 to 3

$$n = 10$$

$$r = 1$$

$$p = .011$$

Where p represents the probability that the observed distribution of positive and negative differences, or any distribution more extreme, may occur when the null hypothesis is true.

The conclusions are the same with this form of the sign test as with the previous form; H_0 is rejected between Quizzes 1 and 3 but not between Quizzes 1 and 2. The results of this test are somewhat more graphic, in that p represents the minimum value of α for which rejection would occur.

The Wilcoxon Signed Ranks test of matched pairs was also applied to the difference data (Ref 11:75-78; 2:309). The same assumptions apply as in the previous test, along with the assumption that the data is ordinally scaled. This test takes into account the relative magnitude of the differences observed as well as their number and sign. In this test, the same difference columns as in the sign test were used. After

discarding the pairs with no difference, the remaining differences were ranked in ascending order of their absolute value. Ties received the arithmetic average of the ranks which would have accrued to them had they differed slightly. After the rank order was established, the signs from the corresponding differences were assigned to each rank value. These values are tabulated on the next page (Table 2).

A value T was defined as the absolute sum of negatively signed ranks. A corresponding critical value, T^* , is tabulated for various values of α and n (Ref 2:309). By the appropriate decision rule, H_0 is rejected if T is less than or equal to T^* . From the signed ranks calculated by this method and set down in Table 2 on the next page, the following results were achieved:

<u>Quiz 1 to 2</u>	<u>Quiz 1 to 3</u>
$n = 12$	$n = 10$
$T = 20.5$	$T = 2.5$
$T^* = 17$	$T^* = 11$

By the decision rule, the null hypothesis is rejected between Quizzes 1 and 3 but not between Quizzes 1 and 2. The results of this test agree with those of the Sign Test.

A second evaluation of the responses to Part 1 of each quiz, not employing the pre-scored key, exposed a questionable set of data. Respondent No. 20 showed considerable understanding of the problem on Quiz 1. His later responses to the overall quizzes showed a maturing understanding of the problem, but he failed to state the specific problem as

Table 2

RANKED DIFFERENCES FOR USE WITH
WILCOXON SIGNED RANKS TEST OF MATCHED PAIRS

Respondent Number	Quiz 1 to 2		Quiz 1 to 3	
	Difference	Signed Rank	Difference	Signed Rank
7	-3	-8	0	-
8	+2	+4.5	0	-
9	-1	-1.5	-1	-2.5
11	+2	+4.5	+2	+6
12	+4	+11	+4	+9
13	0	-	+1	+2.5
14	+3	+8	+2	+6
15	+4	+11	+1	+2.5
16	0	-	0	-
17	+2	+4.5	+3	+8.5
18	+3	+8	+3	+8.5
19	+2	+4.5	+2	+6
20	-4	-11	0	-
21	+1	+1.5	+1	+2.5
22	0	-	0	-

n = 12

T = 20.5

n = 10

T = 2.5

 $\alpha = .05$

required. He "answered the wrong question", dealing in generalities on Quiz 2. As a result, his sequence of scores (4, 0, 4) indicated negative learning after Quiz 2 and no learning overall; an indication that appeared erroneous in his case.

Respondent No. 20's scores were discarded and all the identical tests were run again. The results are compiled in Table 3 on the next page.

Discussion of Quiz 3, Part 3

As stated earlier, the last part of the final quiz was inserted to garner constructive criticism. While the responses gave evidence that several objectives mentioned in the teaching notes were met, their tone was generally laudatory. No criticism was offered. The subject of the five most frequent comments, and their frequency of appearance, are listed below. No other comments appeared more than once.

<u>Comment</u>	<u>Frequency</u>
General comments of approval, such as "interesting" and "enjoyed it". (Each student who made such comments was counted only once.)	7
Recognition of the requirement to apply the tenet of SIMPLIFICATION.	6
Perceived relevance of the case study to the Graduate Systems Analysis program.	4
The realization that data takes on many forms other than numerical.	4
Perceived realism of the case study.	4

All of the responses to this question are listed in Appendix 3.

Table 3
RESULTS OF STATISTICAL TESTS
APPLIED TO CORRECTED DATA

$$\alpha = .05$$

	<u>Quiz 1 to 2</u>	<u>Quiz 1 to 3</u>
<u>Sign Test of Paired Observations</u>		
n =	11	10
r =	2	1
$r(\alpha, n) =$	2	1

Sign Test, Alternate Form

p =	.033	.011
-----	------	------

The appropriate decision rule rejects the null hypothesis in both cases, by both forms of this test.

Wilcoxon Signed Ranks Test

n =	11	10
T =	9.5	2.5
$T^* =$	14	11

The decision rule rejects the null hypothesis in both cases.

Conclusions from Case Testing

The results of the statistical evaluation indicated that "The Trignon Power Plant Problem" case study, when administered according to the teaching notes and the schedule employed in case study testing, meets the ultimate and immediate teaching objectives established for it and set down in Chapter II, Research Methodology, page 15. These teaching objectives are repeated here:

The ultimate teaching objective of the case study was to help the student gain an understanding of the tenet of THE PROBLEM.

The immediate teaching objective was for the student to recognize the importance of this tenet and apply it effectively, in his development of a definition of the problem for analysis.

At the selected significance level (.05), the tests on the uncorrected data failed to reject the null hypothesis between Quizzes 1 and 2, but rejected the null hypothesis between Quizzes 1 and 3. When the data was corrected by removing one outlier, the alternative hypothesis was accepted for all cases, by all tests. This hypothesis was:

H₁: The average understanding of, and ability to apply, the tenet of THE PROBLEM was increased by studying the case.

Classroom discussions and responses to the quizzes gave evidence that some students were achieving some of the other learning objectives set forth in the teaching notes. No attempt was made to draw any conclusions regarding the case study's effectiveness in meeting these objectives.

It appeared in case study testing that more time could be profitably allotted to discussing the case study than was available in the testing schedule. The group had arrived at a very interesting point in their developing understanding of the case, when discussion was stopped because of the requirement to administer the last quiz. They were considering how the problem would change if the analysis of the likelihood of a B-52 striking the Trinon Power Plant had shown that the danger was significant. This information has been incorporated into the teaching notes.

IV. Conclusions and Suggested Future Research

Conclusions

The stated first requirement, that the case study developed here be pertinent to the Graduate Systems Analysis program, was accomplished a priori by the method which was developed during the initial research, to select the case history from which the case study was abstracted (Ref Chap. II, Research Methodology, pp. 10,17). Only case histories of analyses pertinent to the Graduate Systems Analysis program were considered as possible source material. The results from case study testing corroborated the success of this a priori method of accomplishing the requirement, from the students' point of view. Responses to the last part of Quiz 3 contained four comments on the relevance of the case study to the Graduate Systems Analysis program.

Classroom tests of "The Trinon Power Plant Problem", administered according to the teaching notes and the testing plan, produced statistical evidence of the case study's effectiveness in teaching the tenet of THE PROBLEM (Ref. p.15). This conclusion can be extrapolated, from the test group to the universe of Graduate Systems Analysis students and from the specific, defined teaching objective to teaching effectiveness in general. The test results constitute one indicator of the successful accomplishment of the stated objective, which was to determine if the case study was effective as a teaching device.

Several points concerning the employment of case studies in the Graduate Systems Analysis curriculum became evident in the course of this research:

It appears that the results of teaching by employing the case study method are less dependent on the ability of the instructor than the results of teaching the same material through formal lectures would be. A large part of the teaching effectiveness of a case study is determined by the way in which the study is constructed. The instructor certainly exercises considerable control and influence on the learning process, but the case study is designed to stimulate learning through interaction among the students, not through the formal one-way flow of information from instructor to students.

Conversely, it seems that learning to employ case studies most effectively and to steer the learning process smoothly toward predetermined goals is a very complex and difficult accomplishment. In large part, the instructor relinquishes his role of "The Authority", to the group intellect. He must develop the ability to nudge the discussion out of fruitless channels and toward specific learning goals with only an occasional comment. He should avoid rigidity in his own conception of the objectives; it is very possible that discussion will lead the group to worthwhile areas of knowledge that neither the instructor nor the constructor of the case study had anticipated.

One tool of authority that the instructor still possesses, and can use with great effect as a guide for the direction

discussions should take and an emphasis of points, is the quiz. The quizzes used in case testing, for example, were narrowly focussed on the teaching objective to be measured. Simply producing a new set of quiz questions could alter the emphasis in the case study and greatly change the learning outcome.

Each presentation of a case study to a different group of students will probably produce somewhat different learning results. The students' particular areas of interest, their aggregate background, their established leadership patterns, and their perception of the "required" outcomes will all influence the direction in which discussion progresses and the eventual learning outcomes.

A case study could teach different things to a group of Graduate Systems Analysis students at different times in their curriculum. For example, The Trinon Power Plant Problem could be presented to a group of students farther along in the program than the test group was. For the purpose of this example, let us assume that this more senior group has already achieved an understanding of the common ingredients of systems analysis, whether they are called tenets, principles, components or some other term. The case study might then be focussed on various methods of accomplishing an analysis similar to Capt. Masten's, and how these methods compare in time required, other costs, and accuracy of the result.

An entirely different and more sophisticated problem emerges if any of the protagonists are not satisfied that the

probability of an interaction between a B-52 from Oil Burner 28 and the Trinon Power Plant is not negligible. This situation could be the subject of another case study built on the same scenario.

Suggested Future Research

During the research and preparation of this thesis, several subjects emerged which could profitably become the objects of further thesis research projects.

Further testing of this case study could be accomplished to determine such things as its teaching effectiveness relative to the effectiveness of an equal length of time of formal lectures directed toward the same teaching goals.

Variations on the result of the analysis presented in this case study could be developed, showing how the nature of the problem changes with the probability of a collision of a B-52 from Oil Burner 28 into the Trinon Power Plant.

Other case studies in military systems analysis could be developed and tested in the classroom. Continuing effort along these lines by students in the Graduate Systems Analysis program would result in the production of a set of case studies tailored to the educational requirements of the program.

Experience accrued in the conduct of this research indicates that time spent on the refinement of quiz questions, to include pre-testing when possible, would add strength and credibility to any statistical inferences drawn from results of quizzes.

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Appendices

Appendix 1. The Trinon Power Plant Problem

Appendix 2. Teaching Notes

Appendix 3. Responses to Case Study Quizzes

Appendix 1

THE TRINON POWER PLANT PROBLEM

This case study was developed as two cassettes, a scenario and an analysis. The scenario, with its accompanying exhibits, presents all the information necessary for the student to understand the problem. The analysis presents one complete, concise definition of the problem and the consequent analysis. The case study concludes with a report on this analysis.

THE TRINON POWER PLANT PROBLEM

Cassette 1

THE TRINON POWER PLANT PROBLEM

Casette 1.

Bengal 36 contrasted sharply with its surroundings as it jolted through the choppy air 2300 feet above the sea. In the black bottomed, olive drab battle dress which it wore for a war that was half the globe away, it provided the solitary spot of shadow in a world of flashing light. The glare of a clear autumn afternoon fell on the boisterous surface of the North Atlantic, splintering into reflections from wave and whitecap.

The Strategic Air Command B-52, callsign Bengal 36, had just departed the Initial Point for its low altitude, high speed simulated attack on the port facilities at Freebury, Maine. The ragged coast and the islands in Bottle Bay were clearly visible, ahead and to port. The copilot had completed his I. P. call to the Harperville Radar Bomb Scoring Site, Harp RBS, and Bengal 36 was cleared into the maneuver area. His fuel flows were normal, the C. G. was "right on"; everything was boringly, routinely normal.

Without preamble, Bengal 36 started dropping her blunt nose smoothly toward the water.

Startled, the Aircraft Commander exclaimed, "Hey, Chuck. This beast..."

The copilot reacted, and both pilots strained back on their control yokes. The controls stayed forward, and the aircraft's nose continued to drop until Bengal 36 struck the Atlantic.

The rest of the crew was continuing with business as usual during these last eight seconds of Bengal 36's existence. With their lapbelts and shoulder harnesses secured against the often violent buffeting of a low-level run, they had not yet become aware of the slight negative G-load caused by the huge aircraft's pitchover. The Radar Operator, engrossed in his bomb run, gradually lost the maplike radar paint of the approaching coastline and got instead a bright parabola of reflection off the water just ahead. He was reaching in irritation for the antenna tilt knob when he died. The Navigator and the Gunner were engrossed in pre-release checklists. The Electronic Warfare Officer was in voice communication with the Countermeasures Officer at Harp RBS. As he waited for coded scores of his spot jamming effectiveness, he had time to lean idly around his equipment rack for a glance forward. He saw the rough green wall of the Atlantic filling the cockpit windows.

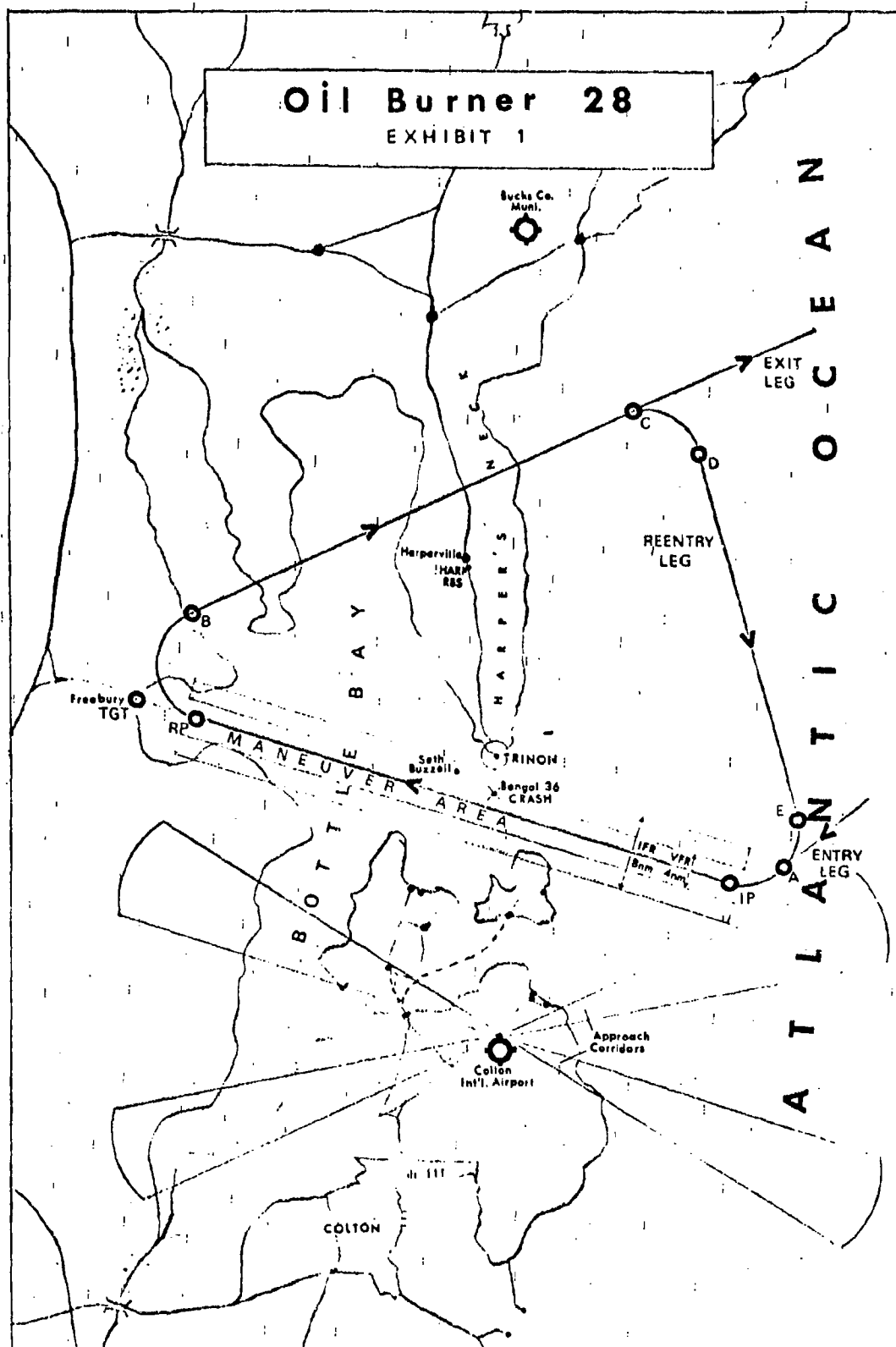
He jabbed a foot at the floor button, keying his mike, and screamed, "MYGODMAYDAYMAYD..."

Seth Buzzell had just emptied and rebaited a lobster pot and was returning it to the rocky bottom of Bottle Bay. As he paid out the line, attached at its other end to the conical red and white float that was Seth's brand, he caught a bright flash in the periphery of his vision. Looking to the southeast, he stared in awe as a vertical column of water sprang several hundred feet into the crisp air, an orange sphere of flame expanding rapidly around its base. As he

watched, still crouched over the gunwale holding the potline, the plume of water broke and fell back and the fireball darkened rapidly. By the time the sound reached him, with a crash so loud that he flinched and sat back jarringly on the thwart, the ball was just greasy black smoke, rising and elongating as it started to drift downwind.

Freebury is an unremarkable village of Downeast Yankees, lobstermen and the entrepreneurs of a collection of businesses that cater reluctantly to the summer tourist trade. For Strategic Air Command, however, it possesses a unique combination of assets: It is within one of the few small pockets of unallocated airspace in the Northeastern United States. It is on the coast, in an area of sparse population. The Begley Boatyard, two large peaked-roofed rectangles of corrugated steel, provides a radar return that nicely simulates a much larger marine industrial facility. All in all, Freebury makes an excellent target for direct, low level simulated bombing runs.

SAC activated the Harperville Radar Bomb Scoring Facility in 1963 after three years of site evaluation, procurement and construction and an expenditure of 1.4 million dollars. Harperville lies in the center of Harper's Neck, a flat peninsula of farmland that separates the upper end of Bottle Bay from the Atlantic. Harp RBS is ideally situated to provide air traffic control and radar bomb scoring for the practice route attacking Freebury, called Oil Burner 28. There are no significant terrain obstructions within a 110-



mile radius. The antennas of Harp RBS are located on a barely discernable 15-acre knob south of town which is, at 48 feet above mean sea level, the highest point of land on the peninsula. Harp therefore enjoys unusually consistent radio and radar contact with the aircraft that it "works". It is a favorite training target, especially in unfavorable weather.

Near the end of 1963, the Tri-State Power Company selected the extreme southern tip of Harper's Neck as the site for its first atomically fueled power plant. This plant, named Trinon, was fueled and put on line in August 1969 and has been operating steadily since then. It is a relatively small power production unit, producing 80,000-90,000 kilowatts with a design capacity of 100,000 kilowatts. It has, however, been of great value to Tri-State in several ways. It is their training site, where all of the company's engineers and technicians learn the peculiarities of atomic pile operation, including the elaborate safety procedures. It has given Tri-State's directors and managers, located in nearby Bangor, an opportunity to study Trinon as a producing element of their network, and to "touch the hardware", acclimating them to this dynamic new source of energy. On a simple cost-accounting evaluation, the plant is not so impressive. It produces power at approximately 1/2 the unit cost of the best fossil fueled plants, but its high initial cost pushes the breakeven date into the late 1990's.

Norman Grant, Tri-State's president, feels personally responsible for the company's investment in Trinon. He is, therefore, very interested in every factor of its operation. He hopes to see the plant's time to breakeven shortened through more and more efficient operation in the interim years. He was, therefore, dismayed to find that the accident liability insurance for Trinon was to be doubled, from \$88,000.00 to \$176,000.00, for its second year of operation. The official announcement referred to "...hazards not previously assessed by the Association, resulting from the frequent proximate operation of military aircraft performing unusual maneuvers...". After several hours' telephone discussions with the management of the Nuclear Power Insurance Association, it became clear that the rate doubling was a more or less arbitrary measure, prompted by the crash of Bengal 36 on 3 September 1970. The insurers felt that this was a necessary interim action while they attempted to evaluate the threat posed to Trinon by the nearby bombing route, O.B. 28. Since they had no actuarial information to apply to such a combination, they had requested an evaluation from the Atomic Energy Commission. Until some specific risk estimates could be formulated, the NPIA would insist on; (1), double premium rates, or (2), cessation of all use of O.B. 28 by Strategic Air Command.

Dr. Robert Fellini, Director of the Licensing Bureau for Commercial Nuclear Devices, Atomic Energy Commission, was angry and frustrated. Angry, because he felt that someone

on his technical staff had committed a dangerous oversight, and frustrated because he could not determine either a single person responsible or the magnitude of the error. Since the licensing documents approving the design and operation of the Trinon Power Plant were over his signature, the error was ultimately his. He had reviewed the 220 page commissioning document and found one key phrase on which he felt the magnitude of the danger to Trinon hinged. This phrase appeared in the engineering specifications for the containment vessel which housed the nuclear pile.

It said, in part, "...The central sphere is calculated with 90% probability to be of sufficient strength to withstand, without rupture, direct collision of a jet aircraft in the 100,000 to 200,000 pound class."

There was some amplification of this statement in the test documents which indicated that the aircraft performance data used in developing these calculations had been for the Boeing 707 cargo aircraft. Impacts had been simulated at the structural speed limitations of the airframe, for several gross weights and angles of impact.

Dr. Fellini scratched a memo to his staff in general, requiring immediate information on the following points:

- (1) How does the B-52 compare with the 707?
- (2) What weapons might be carried on the B-52, and how does this affect the calculations?

He composed a telegram to the Secretary of Defense, to be released over the signature of his chairman. In it, he

requested that SAC be instructed to stop using O.B. 28 until the danger to Trinon was fully assessed. He asked that Air Force be made responsible for a complete review of the tactics and procedures used in low level high speed training flights and at Harp RBS in particular. He suggested that part of the product of this study should be proposals for alternate routes.

He wrote a letter to the Tri-State Power Company, stating that the environmental parameters of the power plant might be compromised by the proximity of Oil Burner 28. He hinted at the possible revocation of Trinon's license to operate.

Three weeks after Bengal 36's demise, Seth Buzzell captivated the Friday night dance at the Grange Hall. This "Dance and Pot-luck Supper" every last Friday of the month was the major social event in Freebury from September until May. Seth had an audience of most of the town when he launched into a twenty minute tirade against SAC, bombers, war and all governments beyond Freebury's Town Council. He was the more startling since his neighbors were not used to hearing more than an occasional phrase from Seth. On this night, though, he was a Daniel Webster. He paced and ranted, displaying at a critical moment a finger size sliver of aircraft aluminum, scorched and melted along one edge. At another point he produced, like a conjurer, two very dead lobsters. Seth was convinced that the wreckage from the B-52 had poisoned the lobsters and, "...who knows what all."

He painted lurid verbal pictures of radiation poisoning invading the bay and the town, never putting bounds on the possibilities of catastrophe.

For two weeks, the lobster catch in Bottle Bay had been very slim and the incidence of dead or dying lobsters in the traps was unusually high. This happened every few years, always as now when the lobsters were moving to their deep winter grounds. This year, however, Seth was haunted by the vision of Bengal 36's violent end. The image crouched in his mind, coloring every subsequent event.

Seth had written an archaic but very specific petition to "the government in Washington", requesting that the Air Force stop their practice bomb runs on Freebury. In the thrall of his fervor, nearly half the men, women and children of Freebury signed his petition. By Monday, many of the townsfolk were having cooler second thoughts. Seth himself, having purged himself in this manner, was amazed and a little embarrassed at his audacity. If he had not already mailed the petition to Congressman Kooney...

Exercise:

1. You are an analyst at Headquarters USAF. Define the problem, from that viewpoint.
2. What are the relevant issues?

Tri-State Power Co.

Serving New England

Macomber Building, Bangor, Maine.

October 5, 1970

Honorable Francis Wheelwright
United States Senate
Washington, D.C. 20510

Dear Frank,

Our technical people are gathering a package of the facts surrounding the unfortunate B-52 crash down here last month, and what this crash might indicate as regards the safety of our nuclear plant, Trinon.

As I promised in our recent telephone conversation, I will keep you informed. I am enclosing the few facts we have assembled to date. Note particularly our insurance rate.


As of the present, it appears that continued use by the Air Force of their bombing practice route, Oil Burner 28, constitutes a hazard to the safe operation of the Trinon Nuclear Power Plant. We will therefore appreciate any assistance you can give us resolving this conflict of requirements. As a first logical step, I would hope that the Air Force will choose to suspend use of that route until the extent of the danger can be assessed.

My warmest regards to Virginia,

Sincerely,

NG/plk

Exhibit 2



CITY OF HARPERVILLE
BUCKS COUNTY ME.
Where Freedom Is Everybody's Thing.

November 20, 1970

Honorable George B. Kooney
House of Representatives
Washington, D.C. 20515

Dear Congressman Kooney:

We are enclosing a copy of a resolution expressing the community concern over the many and persistent rumors we have heard of late, to the effect that the Harperville Radar Bomb Scoring Station may soon be closed.

We would appreciate your help in investigating the truth of these rumors, and in any influence you might be able to exert upon the Air Force to forestall such a closure.

Yours sincerely,

CITY OF HARPERVILLE

James R. Hanna

James R. Hanna
City Administrator

JRH/ilw

enclosure

Exhibit 3

E X T R A C T E D

From the minutes of a meeting of the City Council of Harperville, Maine, which meeting took place on the 20th day of November, 1970:

RESOLUTION

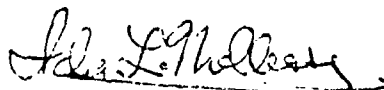
Whereas a large number of the citizens of this city have expressed concern over the apparent plan of the United States Air Force, to close the Harperville Radar Bomb Scoring Facility, and

Whereas said citizens feel that the officers and men, and their families, are valued members of this community and that the operation of the Harperville Facility has contributed significantly to the social and economic welfare of this city,

Therefore, Be It Resolved that the City Council of Harperville does hereby request that the said Radar Facility remain open and functioning.

The resolution was adopted by unanimous voice vote of the Council of the City of Harperville, all members being present.

Upon the Council's recommendation, a copy of this resolution is extracted for presentation to The Honorable George B. Kooney, Representative of the fifth district to the Congress of the United States.



Ida L. Mellesley
Harperville City Clerk

Exhibit 4

U N C L A S S I F I E D

13 22317

PP PP UUUUU

191832Z DEC 70

CSAF

SAC

INFO 14 CEG EASTWOOD AFB MASS

UNCLAS X00S

SAC/DOTO: INFO 14CEG

SUBJECT: OIL BURNER 28

1. EFFECTIVE IMMEDIATELY, SUSPEND ALL FLIGHT ON ROUTE OIL BURNER 28 UNTIL FURTHER NOTICE.
2. UPON COMPLETION OF PLANS FOR SURVEY FLIGHTS AS PER TELECON AF/X00S AND 14CEG/TE THIS DATE, CONTACT AF/X00S FOR SPECIAL CSAF CLEARANCE BY TIME AND DATE FOR SURVEY FLIGHTS ONLY.
3. STUDIES AS REQUIRED PER PREVIOUS CORRESPONDENCE SHOULD BE CONTINUED WITH ALL SPEED PRIOR TO SURVEY FLIGHTS, AS POSSIBLE.
4. MERRY CHRISTMAS

AF/X00S
[Signature]
FRED J. MERTZ, COL, USAF
Asst. Deputy Dir. for Strategic Forces
Directorate of Operations

U N C L A S S I F I E D

Exhibit 5

THE TRINON POWER PLANT PROBLEM

Cassette 2

THE TRINON POWER PLANT PROBLEM

Casette 2.

Captain Judd Masten, USAF, leaned back in his creaking swivel chair and squinted fiercely as he rubbed his temples with the thumb and middle finger of his left hand. He had been reading steadily for the last hour and a half; a polyglot of letters, TWIXs, minutes of meetings and working papers, all dating from the crash of Bengal 36 a year ago.

He had arrived at his bull-pen cubicle in the Pentagon's E-ring fifteen minutes early on this Monday morning, to find a yellow "See me" slip from his division chief, Col. Jerry Williams, skewered on his deskpen. When he was seated in Williams' office, the Colonel had started a half hour briefing by literally dumping the Trinon problem in his lap. He had tossed Masten the bulky manila file folder, held closed by a large steel spring clip, with the comment,

"Well, Judd, today you solo."

Masten had been working in the strategic Weapons Division of the office of the Assistant Chief of Staff for Studies and Analysis, Headquarters, USAF, for nearly a year. He had been a member of two different teams of analysts, the first team studying the effectiveness of a proposed weapon system vis-a-vis the comparable system in being, and the second developing viable mixes of certain weapons and transportation systems to accomplish given tasks. He had

then joined a "briefing team" who presented the results of the second study to the Air Staff and to an assemblage of planners at SAC headquarters. His function on both these projects was that of a statistician. He had been required to manipulate data already collected to illuminate problems already identified by or for the team. He had found this work not unlike the problems he had encountered in school, differing only in that they were generally much more complex and that clear "answers" were seldom forthcoming from the analyses.

This time he was a team of one, assigned to analyze the "Trinon Power Plant Problem" in response to a request from the office of the DCS/Plans & Operations.

His first impression after reading the contents of the Trinon file was one of complete confusion. Through the pages of that file, many different people and organizations clamored for attention, expressing strong views, presenting convincing arguments and righteously demanding actions which were sharply divergent, even directly opposing. With a sigh, he plunged back into the file...

By Friday, Judd was deeply involved in the Trinon situation. He had become familiar with the players and the settings in this real-world drama, and he found to his satisfaction that he was gradually forming an orderly entity out of the seemingly disjoint array of information in the Trinon file. He had spent a day in the library and several hours on the telephone, becoming familiar with the facts, opinions, procedures, regulations, geography and economics that constrained the problem and formed the basis from

which so many different viewpoints had sprung. He had sifted through the various documents many times, extracting lists of pertinent factors, revising and discarding. He finally produced the concise (if irreverent) table shown on the next page.

He also arrived, after many alterations, at this statement of the problem.

"The possibility of a B-52 crashing into the Trinon Nuclear Power Plant and causing a nuclear accident while engaged in a high speed, low level RBS run on Oil Burner 28."

As Masten pondered these results of his week's work, the word "possibility" seemed to emerge from the page and stand out as the crux of the stated problem. As Judd considered the word, he began to get excited about its possible implications. Could he determine the probability of such an occurrence? If so, what implications might that probability have?

Before quitting for the weekend, Judd call LCol. Harry Beams, a Deputy Chief of Operations and Analysis, SAC. LCol. Beams' name had been given to Judd as his point of contact for assistance or information from that command. Masten requested a history of all B-52 flights flown against Freebury via Oil Burner 28, explaining what he was looking for. He received cordial, immediate but somehow a little frosty agreement, with a promise that the requested information would be on the Monday courier flight from Offutt AFB to Andrews AFB.

THE TRINON POWER PLANT PROBLEM

Exhibit 6

AGENCY	PRINCIPALS	DESIRED ACTION	STAKES	MOTIVES
SAC	Many, many	Retain O.B. 28; no ops. change.	How much to relocate HARP RBS ??	\$; Training.
Tri-State	Pres. N. Grant	Continued operation of Trinon; economy.	Insurance \$ (3% of current ops. budget). Future of Nuc. Pwr.	\$; Uncertainty
HARP RBS			SUNK	
Harperville	Town Council	Retain HARP RBS.	How much does HARP spend in Harperville?	Avarice (\$).
Fed. Legislators	Sen. Wheelwright	Get Info.; Interim closure of O.B. 28.	Support	Gratify Tri-State Mgt.
Freemen of Freebury	Cong. Kooney	Get Info.	Votes.	Gratify Constituents.
Nuclear Power Insurance Assn.	Seth Buzzell	Close O.B. 28.	Imaginary.	Hysteria.
AEC Licensing Bureau	Mgt.	Get Info.; Rate Hike or Close O.B. 28.	What is cost of a nuclear accident??	Conservatism (\$); Hysteria.
	Dr. Fellini	Get Info.; Preserve Bureaucracy.	Reputation.	Embarrassment.

On Monday morning, Masten arrived at work with a rough outline of the course he wanted to take with his analysis. His specific goal was to estimate the probability of a B-52 straying off course from Oil Burner 28 and crashing into the Trinon Power Plant. He had extracted several key factors from the Trinon file and other sources:

1. Existing route control procedures at Harperville RBS, in effect since early 1964, require that no aircraft under their surveillance penetrate the vertical cylinder of airspace delineated by a circle of 1-1/2 miles radius whose center is the Trinon Power Plant, from the surface to 20,000 feet. This prohibited area is referred to as "The Circle" by the Surveillance Operators at Harp.

2. The maneuvering portion of any low level, high speed RBS route is a corridor whose centerline is the track from Initial point to Release Point. For aircraft on an IFR (Instrument Flight Rules) clearance, this corridor is 8 n.m. wide. A similar corridor for VFR (Visual Flight Rules) is only 4 n.m. wide.*

3. The present siting of Oil Burner 28 exactly meets both of these restrictions; the track for the maneuvering leg passes 5-1/2 n.m. south of Trinon at its nearest point. A combination of factors rule out a maneuver leg over land to this target.

4. Harp RBS is required to maintain constant radar

* See map, Casette 1, page 54.

contact with the attacking aircraft throughout this leg of an RBS run. Harp is required to abort the run in either of two cases:

- a. Deviation of the aircraft outside the specified corridor limits.
- b. Loss of radar contact for two contiguous sweeps on the Plan Position Indicator at the Surveillance position.

In the event of an aborted RBS run, the aircraft is directed to the corridor centerline and instructed to climb to 10,000 feet.

Knowing these facts, Masten had outlined his analysis to proceed through the following steps:

1. Determine the navigational accuracy to be expected of B-52s performing high speed low level flight on Oil Burner 28 by examining training records and RBS tracking and scoring information.
2. Determine the probability that a B-52 will overfly The Circle, given the present system for aborts.
3. From these calculations and the reliability history of the B-52, calculate the probability of a B-52 crashing into the circle.
4. Estimate the probability of a nuclear accident in the event of such a crash. (A nuclear accident is any event which ruptures the containment vessel, regardless of consequences.)

a. Compare the characteristics of the B-52 with those of the Boeing 707.

b. Compare the area of The Circle with the area profile of the containment vessel.

While he waited impatiently for the arrival of his data from SAC, Judd made some rough calculations on these last two comparisons.

The containment vessel is a spherical section a little less than a hemisphere, or equivalent to the portion of the globe above the 14° latitude line. The circle of the vessel's base, parallel to the earth's surface, represents a close approximation to the profile that the vessel would present to a diving aircraft in all but the shallowest of descents. Assuming for the moment that the probability of a crash within The Circle is uniformly distributed over The Circle, the probability of such a crash striking the vessel is approximated by the square of the ratio of the radius of the containment vessel, 60 feet, to the radius of The Circle, 9120 feet. This ratio is $4.33 \cdot 10^{-5}$ or a probability of less than 1 in 10,000 that a crash within The Circle will strike the containment vessel.

Judd did not yet have enough gross weight and speed data to compare the pertinent characteristics of the B-52 with those of Boeing 707. He had, however, collected several facts which indicated that the B-52, as normally configured for a high speed low level training mission, would fall within the weight and speed envelope used to calculate the impact data

for the containment vessel. He had determined that bombs are never carried on these missions. Since the two aircraft are similar as to general structure and mass distribution (aluminum frame, semi-monocoque fuselages, podded external engines and wet wings), there was no reason to assume that impact data would differ significantly for the two aircraft at like gross weights and speeds. It only remained to determine empirically how often aircraft with gross weights exceeding the 200,000-pound test weight were engaged in high speed low level training flights on Oil Burner 28, and the probability sought in step 4, could be calculated. Masten expected this information to be contained in the data from SAC.

In mid-afternoon, a messenger arrived at Masten's cubicle with the data from SAC - in six large corrugated cartons! Judd started to sort through the reams of fan-folded computer print-outs, rows and columns of figures headed by cryptic symbols. He had nearly given up on the whole lot when he found a pair of manuals in the bottom of a carton. These manuals turned out to hold the keys to interpreting the massed data. As Masten studied the manuals, he found that SAC's data had been collected in great detail and aggregated in many different ways, and LCol. Beams had simply retrieved all data pertaining to high speed low level runs on Oil Burner 28 and sent them along. Judd had to admit, on reflection, that this was what he had asked for. He reconsidered their conversation on Friday of the week before and realized that Beams was piqued at the "intrusion" of strangers

from higher headquarters into what he probably considered his area of responsibility for analyses. Judd skimmed the masses of data again to ascertain what they contained, and then called LCol. Beams. He started the conversation by complementing Beams on the completeness of the data, and thanked him effusively for its rapid delivery. He then outlined his plan of attack on the problem. He explained that he would also need some summarized data on such things as B-52 crashes while on low level high speed RBS runs, their causes, and any breakouts by time or route of crashes per hour flown. Since this approach made Judd a user of SAC's analyses and not a competitor, he noticed an immediate warming of LCol. Beams' attitude. Beams said this information was available, promised to telephone it to Judd within an hour, and asked to be kept informed of his progress.

By Thursday, Masten had sifted and gathered the data pertinent to his analysis, made the necessary calculations, and was prepared to write up the results of his work.

Exercise:

1. Now that you have read the complete analysis accomplished by Capt. Masten, restate your definition of the problem.
2. What are the relevant issues?

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, D.C. 20330



REPLY TO
ATTN OF: AF/SAS

16 September 1971

SUBJECT: The Trinon Power Plant Problem

TO: AF/X00S, Col. Fred J. Mertz

1. Reference your request for an analysis of the Trinon Power Plant Problem. Our analysis focuses on the probability of a B-52 colliding with the Trinon Nuclear Power Plant while engaged in a high speed, low level radar bomb scoring run on Oil Burner 28. The analysis proceeded as follows:

Step 1. Calculation of the probability that a B-52 so engaged will overfly the restricted area designated by a circle of 1-1/2 mile radius centered on the Trinon plant.

Step 2. Calculation of the probability that a B-52 which overflies the circle will crash into it.

Step 3. Estimation of the probability of a nuclear accident resulting from such a crash.

2. The analysis produced the following results:

(1) The probability that a B-52 engaged in a high speed low level radar bomb scoring run on Oil Burner 28 will overfly the restricted area is $2.14 \cdot 10^{-6}$.

The probability of such an overflight occurring in any year is $5.85 \cdot 10^{-4}$.

The probability of such an overflight ever occurring is $1.17 \cdot 10^{-2}$.

(2) The probability that a B-52 engaged in a high speed low level radar bomb scoring run on Oil Burner 28 will crash into the restricted area is less than $2.57 \cdot 10^{-13}$.

The probability that a B-52 so engaged will crash into the restricted area in any given year is less than $7.02 \cdot 10^{-11}$.

Exhibit 7

The probability that a B-52 so engaged will ever crash into the restricted area is less than $1.404 \cdot 10^{-9}$.

(3) The estimated probability of such a crash causing a nuclear accident is $6.28 \cdot 10^{-6}$.

The estimated probability of a nuclear accident occurring in any given year by reason of such a crash is $4.40 \cdot 10^{-16}$.

The estimated probability of a nuclear accident ever occurring by reason of such a crash is $8.80 \cdot 10^{-15}$.

3. Estimates of the probability of occurrence of a nuclear accident due to natural causes (earthquake, fissure, storm or meteorite) in any given year of Trinon's existence were developed during the plant sitting phase of Trinon's conception. These estimates were developed by the Atomic Energy Commission in cooperation with the Geology Department of the University of Maine. Documents included in the plant's commissioning package place the total risk per year of a nuclear accident caused by any of the natural hazards at $1.82 \cdot 10^{-14}$. This is approximately 41 times the risk of a nuclear accident caused by a B-52 colliding with Trinon, as calculated in this analysis.

4. The calculations through which the results of this analysis were produced, are attached.



Jerry Williams, Col, USAF
Chief, Strat. Wpns. Division
ACS/Studies and Analysis

1 Atch, Calculations.

CALCULATIONS

The Trinon Power Plant Problem

Records from seven years' operation of Harp RBS show 1912 high speed, low level RBS runs were attempted in that time.

SAC estimates that their usage of Oil Burner 28 will probably decline, and certainly not increase, over the remaining operational life of the B-52, which they predict to be a maximum of twenty years. Runs per year are therefore, conservatively predicted to average not more than 273.

There has been only 1 failure of the (doubly redundant) radio link between Harp RBS and a B-52 on Oil Burner 28. Probability of radio failure is $5.23 \cdot 10^{-4}$.

SAC has determined that navigation errors are normally distributed. Crosstrack navigational error for the 1912 runs on O.B. 28, measured at release point, reveal only 16 in excess of 4 miles.

This suggests a normal distribution of crosstrack error with $\sigma = 1.52$, and yields the probability that any given B-52 on O.B. 28 will overfly the circle, of .0041, neglecting the established abort procedure.

$$N(x, \sigma) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-5.5)^2}{2\sigma^2}}; \int_{-1.5}^{1.5} N(x, \sigma) dx = .0041$$

Considering the abort procedure, the probability that any flight will overfly the circle becomes;

$$(5.23 \cdot 10^{-4})(.0041) = \underline{2.14 \cdot 10^{-6}}$$

This holds for the worst case in which all flights are on IFR clearances.

The product of this probability with 273 runs/year and 20 times that product yield the annual and absolute probabilities of an overflight, respectively.

SAC employed the data from nearly half a million runs to conclude that the probability of a crash per low level run is $4.80 \cdot 10^{-6}$. Since low level routes average 120 miles, the probability of a crash per mile of low level flight is $4.00 \cdot 10^{-8}$.

Calculations made earlier yielded the probability $4.33 \cdot 10^{-5}$ that a crash in the circle would strike Trinon. The calculations assumed uniform probability distribution for a crash within the circle. Clearly, the actual probability of a crash in the circle striking Trinon will be less than this, when crosstrack errors are normally distributed.

Assuming independence between navigation errors and probability of crash, the probability that a B-52 engaged in a high speed, low level RBS run on Oil Burner 28 will crash in the 3-mile square enclosing the circle, two sides of which parallel the aircraft track, is;

$$3(4.00 \cdot 10^{-8})(2.14 \cdot 10^{-6}) = \underline{2.57 \cdot 10^{-13}}$$

Since this square encloses the circle, the probability of a crash in the circle is clearly less.

The product of this probability with 273 runs/year and 20 times that product yield the annual and absolute probabilities of a crash in the circle, respectively.

Only 5% of B-52s enter high speed low level legs at gross weights in excess of 200,000 pounds. Assuming that 5% of all collisions with Trinon by aircraft less than 200,000 pounds and 100% of all collisions with Trinon by aircraft exceeding 200,000 pounds cause nuclear accidents, 14.5% of those aircraft that strike Trinon will cause nuclear accidents.

The probability that a crash in the circle will cause a nuclear accident is less than;

$$(.145)(4.33 \cdot 10^{-5}) = \underline{.628 \cdot 10^{-5}}$$

The probability of a nuclear accident occurring in any given year by reason of such a crash is therefore, less than;

$$(6.28 \cdot 10^{-6})(273)(2.57 \cdot 10^{-13}) = \underline{4.40 \cdot 10^{-16}}$$

The probability of a nuclear accident ever occurring by reason of such a crash is;

$$(20)(4.40 \cdot 10^{-16}) = \underline{8.80 \cdot 10^{-15}}$$

Appendix 2

TEACHING NOTES

These notes are a compendium of ideas and observations accrued during case study development and testing. They certainly constitute no more than suggestions as to some possible techniques for administering this case study. Subsequent classroom experience with the study should suggest addenda or corrections to the teaching notes.

Appendix 2

Teaching Notes

The "Trinon Power Plant Problem" case study is composed of two separately bound cassettes, a scenario and an analysis.

Cassette 1

The first objective of this cassette, the scenario, is to serve as a reminder that data may take many forms besides neat rows of numbers. This fact seems obvious when stated explicitly, but the student becomes habituated to the ready availability of numerical data, in a form directly employable in his practice manipulations. As a result, he tends to think of "data as synonymous with "numerical data". Data are known, assumed or conceded facts from which an inference can be drawn. Ideas, emotions and biases are all data if they are in the possession of a decision-maker and germane to a decision at hand.

This cassette also establishes the requirement for applying the tenet of SIMPLIFICATION*. The scenario contains many distracting facts, purposeful omissions and tempting areas for irrelevant investigation. For example, why did Bengal 36 crash? Some students will probably want to pursue this line.

* The tenet of SIMPLIFICATION was defined thus: "The analyst reduces problems to workable proportions by identifying variables and parameters to which the system under analysis can be shown to be functionally related, and conversely, eliminating those variables to which the system remains invariate or relatively insensitive. (This tenet is the underlying rationale for the technique of modeling.)

In a real analysis this would lead to a massive source of data; accident investigation reports, board findings, possible changes to operational procedures and tactics, and so on. The product of all this material would probably furnish at best a single data point pertinent to possible interaction between the Trinon Power Plant and B-52's from Oil Burner 28.

Some facts are presented only indirectly, such as the restriction against moving the route southward but still terminating on Freebury. The map shows approach corridors to Colton International Airport closely abutting Oil Burner 28 on the South. This fact combined with Freebury's location in "...one of the few small pockets of unallocated airspace in the Northeastern United States." (p. 53) and the contention from SAC that "A combination of factors rule out a maneuver leg over land to this target." (p. 69) should lead the student to conclude that relocation of Oil Burner 28 is not feasible if Freebury is to be the target. The last fact is given in the analysis, Casette 2. Should discussion progress to the point that it is required before the analysis has been distributed, it is included here for the instructor's use.

Casette 2 focusses on the primary objective of the case study, elucidation of the tenet of THE PROBLEM*. In order that the students observe this tenet in application, it is desirable that they read Casette 1 with certain reading

* The tenet of THE PROBLEM was defined thus: "The analyst must identify the specific problem at hand; its components, objectives and constraints."

objectives preconceived.

1. He should determine the components and the bounds of the system under analysis. Any attempt to define the problem before the system is clearly identified will probably produce sub-optimal or parochial definitions.

2. The student should be asked to state precisely a root problem in this situation, from the point of view of the Air Force at Headquarters USAF level. He should compare this with the problem as probably seen by the other protagonists. He should consider how he would start to analyze this problem; the kinds of data he would need, the methods he would expect to employ and the form he would expect his results to take.

3. He should be instructed to look for issues among the parties interested in the problem, and their protagonists.

The material in the scenario is intended to be read and discussed in the course of one (50 minute) class period. The suggested teaching technique is to list a set of reading objectives similar to those stated above, distribute the scenarios, and allow the class a few minutes to read and think about them. The class should then be encouraged to discuss and compare their various statements of the problem, and attempt to agree on a definition acceptable to the group. If divergent opinion persists, a return to the question of what comprises the system under analysis should help crystalize the definition of the problem by exposing its parameters and its bounds.

Questions used in the classroom testing of the case study are included in the cassette as an exercise (p. 59).

Student discussions may require clarification of several details not covered in the cassette. Some of these details appear in Cassette 2, and others are not given at all. They are included here for the instructor to present them if the requirement emerges.

(1) All miles are nautical miles.

(2) Harp RBS is a permanent installation. None of the equipment or facilities are mobile or readily transportable. It would cost more to relocate Harp RBS in 1972-1973 than the original 1.4 million dollars the site cost. An entirely new facility could be built for essentially the same cost.

(3) Bombs are never carried on RBS runs.

(4) The crash of Bengal 36 is apparently an isolated incident; there have not been a series of such crashes. Should a student or group of students desire to pursue the fruitless course of investigating Bengal 36's accident, the instructor may choose to abet this pursuit. He can ad-lib the facts of an accident investigation to any degree of detail he desires, based on the following outline of facts:

(a) There were no survivors.

(b) Diving recovery teams found no clues as to the cause of the accident.

(c) The accident investigation board found no abnormalities in the aircraft maintenance history or the records of the crew. The board terminated the investigation

After five months, drawing no conclusions as to the cause of the crash.

Repeated use of this case study would undoubtedly expose other details whose addition to this list would facilitate the study's use.

Casette 2

This cassette is directed at the primary objective of the case study; elucidation of THE PROBLEM as defined earlier. An analysis is presented from its inception to its conclusion, demonstrating how exact identification and concise statement of the problem can illuminate the course the analysis should take. This developing analysis also demonstrates the application of the tenet of SIMPLIFICATION. The unique feature of this case, and one reason it was selected to teach the tenet of THE PROBLEM, is that once the problem is clearly identified, a rather simple analysis shows that it is not significant, and therefore not a problem at all! The fact that Capt. Masten's analysis actually eliminated the problem is not stated explicitly; the student should conclude this for himself.

The discussion following study of Casette 2 should be a continuation of the discussion following Casette 1. The class should strive for a common definition of the problem. The same instructor's list of amplifying details applies. Since Capt. Masten's definition is given, the class may choose to adopt it. Discussion can then proceed to some very interesting "what ifs". What if one of the parties does not

consider the computed probability of interaction to be insignificant? What if the calculations had yielded a higher probability of interaction, one that all parties considered significant? How would the statement of the problem change? These subjects can only be posed and conjectured upon: they depart rapidly from the body of data presented in the case study. Their consideration is probably valuable, however. Changing the problem in this manner helps the student gain insight into the structure and composition of problems in general.

As with Casette 1, this cassette was designed to be read and discussed in the course of one 50-minute period. Case testing revealed that more time for discussion would probably contribute significantly to the students' assimilation of the learning objectives.

A closing statement by the instructor outlining the outcome in the real case, from which the study was abstracted, vitalizes the exercise for the students. This outcome was:

The actual analysis was performed in much the same manner as the case study version. The real analysts performed an integration in two dimensions across the probability space represented by "The Circle", rather than the simpler summing of probability in the square that encloses "The Circle", used in the case study. The integral was only integrable in one dimension; the integration in the second dimension was performed graphically. This could have been accomplished using any of a number of methods for approximating an integral,

such as the trapeziodal rule, Simpson's Rule, or an automated version of one of these (Ref 5:462-467). The product of the actual analysis was a probability of interaction between a B-52 from a low-level high-speed RBS route and a certain nuclear power plant, as was the product of the case study analysis. The actual analysis contained no comparative probability of a nuclear accident caused by nature. The analysts relied on the very low probability of an interaction to make their point.

The Office of Primary Responsibility for the problem, at Headquarters, USAF, received thanks and tacit endorsement of the analysis from the power company and the Atomic Energy Commission. Insurers, legislators and all other parties were satisfied that no problem existed. Strategic Air Command was shortly using the route again, with a slight deviation in the flight path that provided a few more miles lateral clearance from the power plant site.

Appendix 3

RESPONSES TO QUIZZES

Appendix 3

Responses to Quizzes

QUIZ 1

1. You are an analyst at Headquarters USAF. Define the problem, from that viewpoint.

Student No. 7

"What is the probability of a nuclear disaster due to a B-52 flying the Oil Burner 28 route, colliding with the Trinon power plant?"

Score 9

Student No. 8

"There is some probability that an aircraft using OB-28 and the HARP RBS will crash in the OB-28 area." Score 4

Student No. 9

"1. Does the threat of aircraft collision with Trinon exist?

2. If so, to what degree will it affect

- a. the Air Force
- b. the public

3. What are the alternatives?

- a. continue
- b. reroute OB-28"

Score 4

Student No. 11

"What is the probability of a SAC B-52 colliding with the Trinon power plant?"

Score 5

Student No. 12

"The proto-problem is to clearly define the issues and conflicts involved. The issue of safety, through probabilistically small, is real. This should be quantified as well as possible and measures taken to reduce risk to an objectively defined minimum- note a. below. There appears to be an economic conflict between money for insurance increase to Trinon and money for SAC relocation and money in town revenue. Can this be quantified?

- a. All things involve risk-reduction to zero risk is impossible. Quantify B-52 vs 707 crash comparison, possibly also earthquake or tsunami." Score 0

Student No. 13

"Which of the following three courses of action should be taken?

1. Continue operation as before on OB-28 and at Harperville RBSF.
2. Find an alternative low level bombing route that will utilize the HRBSF.
3. Discontinue the OB-28 and close the Harperville facility." Score 1

Student No. 14

"The problem is the danger to the Trinon plant caused by the use of OB-28 by SAC B-52's. Both actual and imagined danger are significant problems for the A.F." Score 3

Student No. 15

"Is there really any need to can OB-28 just because there exists an atomic reactor in the nearby vicinity?"

Score 4

Student No. 16

"The problem seems to be determining the likelihood of a B-52 causing a nuclear accident by crashing into the Trinon power plant."

Score 6

Student No. 17

"Reconciliation of AF interests (i.e., maintaining or training for SAC low-level tactics) with those interests of the private citizens involved."

Score 0

Student No. 18

"Does the continued use of OB-28 constitute a significant hazard to the safe operation of the nuclear plant?"

Score 4

Student No. 19

"The problem is that there exists a possibility of a catastrophic accident. The accident is using Harp RM OB-28 NS L. L. crashing into the nuclear power plant."

Score 7

Student No. 20

"The problem begins with a definition of the danger present with the operation of OB-28 in proximity to Trinon. However, it would appear that the relevant part of this problem is to investigate the financial and social costs to the Air

Force and U.S. Government of following possible courses of action with regards to OB-28." Score 4

Student No. 21

"Should OB-28 be retained as SAC training route?" Score 1

Student No. 22

"What is the probability that a B-52 on a low-altitude high-speed bomb simulation will crash into Trignon power plant." Score 6

Quiz 2

1. Now that you have read the complete analysis accomplished by Capt. Masten, restate your definition of the problem.

Student No. 7

"To determine the probability of a nuclear disaster due to B-52 crash into the Trinon power plant." Score 6

Student No. 8

"There is a possibility that a B-52 aircraft will crash into Trinon power plant and cause a nuclear accident." Score 6

Student No. 9

"Problem: Is there a probability that a nuclear accident will occur, and if so, what effect will it have on the Air Force and the public." Score 3

Student No. 11

"What is the probability of a SAC B-52 crashing into the Trinon power plant and resulting in a nuclear accident, relative to costs incurred through possible relocation of the RBS site." Score 7

Student No. 12

"The problem is to develop a concise statement of the relevant issues, showing the true extent of the crash hazard to be weighed against the benefits of retaining OB-28. If OB-28 isn't worth it, dump it. If it is, develop a convincing brief on why it should be retained." Score 4

Student No. 13

"What action should be taken regarding OB-28?"

Score 1

Student No. 14

"What danger does AF use of OB-28 by SAC B-52's pose for Trinon power plant, re: crash of said B-52 on or near the plant."

Score 6

Student No. 15

"What threat, if any, does a B-52 flying a low-level, high-speed bomb run present insofar as the Trinon power plant is concerned (i.e., what is the likelihood of its ever crashing into the plant and causing a nuclear accident?)?"

Score 8

Student No. 16

"I think my definition of the problem is still the same. I agree with Masten in that the problem lies in determining the threat to the power plant from a B-52 crash. If the public and Congress can be convinced the threat is minimal as per Masten's analysis, I think the problem can be solved."

Score 6

Student No. 17

"Can the best interests of the parties involved be served if it can be shown that the probability and "chance" estimates claimed by the insurance company, the power company, and the others are in error."

Score 2

Student No. 18

"The probability that a B-52 will crash into the power site causing a nuclear accident. Should OB-28 continue to be used?"

Score 7

Student No. 19

"What is the probability that a B-52 will crash into the power plant and cause a nuc. explosion, while it is engaged in operations at HARP RBS and OB-28."

Score 9

Student No. 20

"The problem is to identify viable USAF alternatives and to estimate their relative "social" and financial costs. The identification of strong factors affecting each alternative should be pointed out for the party ultimately responsible for the decision."

Score 0

Student No. 21

"Should runs on OB-28 be continued or discontinued?"

Score 2

Student No. 22

- "a. Find the probability that a B-52 will crash into Trinon.
- b. Find the probability that a B-52 crash will rupture the containment vessel."

Score 6

Quiz 3

1. How do you define the problem now? (From the same viewpoint used on the previous quizzes.)

Student No. 7

"We still need to define the actual risk of disaster due to a bomber using the run impacting the nuclear plant, and to determine 1. whether there is sufficient reason to close the run, or 2. if the run should be retained as is."

Score 9

Student No. 8

"The Tristate Power Company, and the company which insures the Trinon facility have to be convinced that no danger is imposed on the Trinon facility by existence of OB-28."

Score 4

Student No. 9

"1. Is there a possibility of a nuclear accident?

2. If so, how great, and what are the alternatives?"

Score 3

Student No. 11

"Not much change from previous answers-except to attempt to analyze the non-quantifiable factors after crunching out any "relevant" numbers."

Score 7

Student No. 12

"Same- the AF still needs a handle on the problem; the issue needs to be put to bed rather than permitted to die."

Score 4

Student No. 13

"Whether to stop flights on OB-28 and close the HRBSF or continue current operation." Score 2

Student No. 14

"The problem for the AF is:

1. SAC - if OB-28 essential to our training, how dangerous is it for Trinon? Probability of an accident is so low that it doesn't appear to be significant.
2. Since probability of accident is so low, how can AF sell its findings to the civil community, the AEC, and the insuring agency, so these findings will be accepted?" Score 5

Student No. 15

"To determine whether or not OB-28 should be continued or dropped. Convincing the public there is no meaningful probability of a crash ever occurring at the reactor plant." Score 5

Student No. 16

"I still see the problem the same way." Score 6

Student No. 17

"Problem is still how to resolve the conflict between the principles, one group who wants to restrict use of OB-28 and one group who wants to retain use. Problem now, however, becomes one of convincing the insurance company of accuracy of estimate of probability." Score 3

Student No. 18

"No change."

Score 7

Student No. 19

"No change."

Score 9

Student No. 20

"No change with exception of maybe using a wait-and-see policy after cranking out the probability figure to see if this was enough evidence to sway insurance company to lower rates and satisfy people all down the line from Trinon to AEC to Congress to USAF. This might avoid further analysis into costs, etc!"

Score 4

Student No. 21

"Should OB-28's use be continued or discontinued?"

Score 2

Student No. 22

"No change."

Score 6

Quiz 3

3. Comment on anything about the case study; the content, the method, the format. What did you learn?

Student No. 7

"This appears to be a good case, in that it requires the reader to separate the relevant from the irrelevant material."

Student No. 8

"Learned numbers are only one step in the total analysis."

Student No. 9

"Gives some insight into "structuring" a problem, and discarding irrelevant facts."

Student No. 11

"Very interesting case- seemed to be more real life than some of the artificial cases we have had before. Good example of the type of problems we might be exposed to as analysts. It was interesting to see the approach of a professional analyst to such a complex problem. I learned of some of the difficulties involved in separating relevant from non-relevant information, plus separating quantifiable and non-quantifiable info."

Student No. 12

"A re-reading of the case usually permits a better view of the facts. As I progressed thru the study, both in reading and discussion, some pts. of relevance and tangency were brought

and reinforced. Some connections not observed in the first reading and discussion were made."

Student No. 13

"This case seems much more relevant to our future jobs than cases we have previously studied."

Student No. 14

"The problem changed as the probability (however questionable) of an accident was found."

Student No. 15

"Case extremely interesting. There are indeed no "nice" solutions to most complex problems that crop up among analysts. Numbers may have no meaning or great significance depending on how one looks at them."

Student No. 16

"Really enjoyed it. It was a pleasure addressing a case that was "blue suit" as opposed to "grey flannel suit" implications. I don't know what we'll see later on in the program, but this kind of thing seems to have great potential as a teaching aid for analysts in our situation. I hope we see more of it. Any practice in defining problems and handling sticky questions will certainly be beneficial as was this case."

Student No. 17

"I was able to relate to an analysis applicable to an

AF problem such as this better than other business-type cases that I have studied."

Student No. 18

"A real problem in analysis such as this is both refreshing and of great benefit."

Student No. 19

"The format of the case study made it fairly easy to pick out what I consider to be the relevant issues. The use of the matrix by Masten seems like a worthwhile way to organize the various issues. The content was of special interest since it comes from the real world."

Student No. 20

"Good method to check and see if students can have their own opinions swayed by a presented solution. Students should seek out other considerations and issues not presented and determine their relative impact on the final outcome of the problem. Throwing in all the "smoke" in the description of the problem in good ideas to see if students can see through it."

Student No. 21

"Interesting and seemingly closer to "real world" than many other case studies.

Content seemed sufficient to attack the problem from our view.

Method- possibly would have been better to do the parts consecutive in time."

Student No. 22

"Analysis of case should include qualitative as well as quantitative issues."

Vita

Clifford Miller was born in Clairmont, New Hampshire on 10 March 1932. He graduated from Laconia High School, Laconia, New Hampshire in 1950. He enlisted in the Air Force in 1953, and received his commission and Aircraft Observer's wings in 1955. He served as a crewmember in Strategic Air Command, on B-36 and B-52 aircraft. In 1962, he obtained a B.S. Degree in Electrical Engineering from Oklahoma State University, under the auspices of the Air Force Institute of Technology. He served as a Communications-Electronics Officer in several capacities, and attended the Staff Communications-Electronics Course (OAR-3011) at Keesler AFB, Miss. Just prior to returning to the Air Force Institute of Technology, he was a navigator on EC-121 aircraft in Aerospace Defense Command, flying from California, from Thailand and several locations in the Orient.

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